FERTILIZING CONNECTICUT TOBACCO

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FERTILIZING CONNECTICUT TOBACCO

T. R. Swanback and P. J. Anderson

Tobacco is grown annually on about 17,000 acres of land in Connecticut. It is largely concentrated in the Connecticut Valley along both sides of the Connecticut River from Middletown north to the Massachusetts state line, mostly in the towns of Avon, Bloomfield, East Granby, East Hartford, East Windsor, Ellington, Enfield, Glastonbury, Granby, Manchester, Portland, Simsbury, Somers, South Windsor, Suffield, Vernon, Windsor and Windsor Locks. A small acreage is still grown in the Housatonic Valley about New Milford.

All Connecticut tobacco is grown for use in cigars. The Shade type is grown primarily for cigar wrappers (the outer layer). Broadleaf and Havana Seed, the other two types grown here, are used for cigar binders (the layer just under the wrapper). The fertilizer requirement of all three types is essentially the same, although some minor differences for Shade are mentioned in the text of this bulletin.

The tobacco soils are sandy loams of varying degrees of fineness, classified in the Merrimac, Agawam, Enfield and Manchester series, and, to a lesser extent, in the Hartford and Cheshire series. The Merrimac and Agawam types comprise the flat terraces along the Connecticut and Housatonic rivers. The Enfield and Manchester soils occur on gently rolling, somewhat higher areas. A little tobacco is grown on Wethersfield loam and Suffield clay loam but these two types are generally too heavy for producing highest quality tobacco. Most of the tobacco land is so flat that erosion is seldom a serious problem.

The best subsoils are fine or medium sandy loams with good water retentive capacity. Clay or "hard pan" subsoil is not satisfactory because it does not permit good drainage. Gravel or coarse sand subsoil permits too much leaching of fertilizer and drought injury in dry weather.

The average tobacco soil contains about 3 per cent organic matter with a total nitrogen content of about .15 per cent. This small amount of nitrogen becomes available very slowly, hence the necessity for heavy nitrogen fertilization.

Old tobacco soils contain large amounts of phosphorus which accumulates from successive applications of much more than the seasonal requirement of the crop. Phosphorus does not leach away. Hence, in the fertilizer it is of less importance than nitrogen and potash.

These soils contain large quantities of potash but it is too slowly available to be of much use to the crop. Therefore, heavy annual applications of potash are necessary.

Calcium and magnesium are not found in sufficient amount in these soils for best results and must be augmented in the fertilizer mixture.

The optimum soil reaction is 5.0 to 5.6 pH. Since these soils tend to become more acid than this, it is often necessary to add lime in small amounts, either in the fertilizer or as a separate application. Reactions above 5.6 must be avoided because the black rootrot fungus thrives in such soils.

The object of applying fertilizer is to augment the native soil supply of each of these plant nutrients sufficiently to place the optimum amount within easy reach of tobacco roots at all times.

Exhaustion of nutrients is accentuated by the common practice of growing tobacco year after year on the same land. Crop rotation as a rule is not an economical practice on Connecticut tobacco land. Exhausted plant food supplies can be replenished more economically by heavy applications of commercial fertilizer than by crop rotation or resting the land.

The nutrient requirement of tobacco is heavier and more expensive than that of any other crop grown in Connecticut, with the possible exception of some vegetables. At present prices, it costs about 125 dollars an acre to fertilize tobacco properly. This is the farmer's heaviest cash outlay, outside the labor expense (if he does not depend on his family for the work).

The Connecticut Agricultural Experiment Station from the very date of its establishment in 1875 has conducted experiments designed to solve the many complex and changing problems of tobacco fertilization. Even before that date Johnson (1872), who later became the first director of the Experiment Station, published extensive analyses of cured tobacco samples and of fertilizers used on tobacco land in that period (63). From 1892 to 1897 Jenkins (59), the second director of the Experiment Station, in cooperation with the Connecticut Tobacco Experiment Company, conducted intensive fertilizer experiments at Poquonock with such scientific thoroughness that the principles established at that time are still the basis of our fertilizer formulas. From the establishment of the Tobacco Substation in 1922 up to the present year, fertilizer experiments have been in continuous operation and the field tests have occupied the greater part of the Station farm at Windsor. Full details of methods and tabulated data of most of these experiments have been published in our annual reports and several special bulletins.

Most of these annual reports and bulletins, as well as all of those issued previous to the establishment of the Tobacco Substation, are no longer available for distribution. Moreover, each of the articles in these reports deals with only one phase or element of the tobacco fertilizer. The grower or student who wishes to learn what is known about tobacco fertilization in general or about a particular phase of

it, is confronted with a tedious task of locating the information he needs.

Therefore, the purpose of the present bulletin is to condense in one publication the pertinent and essential information on tobacco fertilization obtained by three quarters of a century of experiment, analyses and experience. All details of methods, analytical and tabular material, argument and the like are omitted. However, for the student who wishes to go more deeply into these matters, we add on pages 44 to 47 a reference list of tobacco fertilizer articles published by the Station or its staff. These are referred to by numbers throughout the text of the bulletin.

HISTORICAL

In the three century history of tobacco culture in New England, the use of commercial chemicals or mixtures of chemicals and organic by-products, is fairly recent. Such materials were not utilized until the middle of the nineteenth century. Very little was recorded about fertilization of tobacco in colonial times. It may be assumed, however, that the few materials that were known at that time for enriching the soil for other crops, were also used for tobacco. The value of stable manure for increasing crop growth was well known long before the discovery of America and undoubtedly this was the first fertilizing material used by the early tobacco growers. All publications up to the middle of the nineteenth century which we have seen show that manure was the all-important source of fertility for tobacco lands. The value of wood ashes and animal bones was also known to the colonists and these materials were undoubtedly applied to tobacco. Ground bone, however, was not used in America previous to 1825. The use of fish or fish scrap and seaweeds also dates from colonial times but there is no record to show how extensively they were used for tobacco.

A new era of tobacco fertilization started with the first heavy importation of Peruvian guano about 1843. Guano is the dry excrement of fish-eating sea birds deposited in large amounts on arid islands off the west coast of South America. It contains 12 to 14 per cent of nitrogen besides considerable amounts of the other essential plant foods. It met with immediate favor among tobacco growers and was extensively used by them from 1845 to 1875, when the best South American supplies began to fail. Chilean nitrate of soda was first imported in 1830 and was being used for tobacco to some extent by the middle of the century. Superphosphate, originally made by treating bones with sulfuric acid, was first used here in 1852. Later, made by treating rock phosphate, it was destined to play an important role in tobacco fertilization, although growers have generally preferred ground bone or precipitated bone.

German potash salts were first used about 1870 and, although "Kainite" was soon discarded because of its content of chlorine, the sulfate salt soon gained a permanent place in the tobacco formula.

Mixed fertilizers came into use between 1850 and 1860. Bradley's formula and Maples formula became popular with tobacco growers soon afterwards.

A list of tobacco fertilizers that were used about 1870 was compiled by Johnson (63) from a questionnaire which he sent to representative tobacco growers in Connecticut and Massachusetts. Rated in the order of frequency in the answers to the questionnaire they were:

1. Yard manure (used by all)
2. Peruvian guano
3. Phosphate (bone or superphosphate)
4. Gypsum (land plaster)
5. Fish scrap
6. Tobacco stalks
7. Wood ashes
8. Seaweed
9. Bradley's fertilizer

Up to this time, growers depended mostly on animal manures, the by-products of the slaughter house and the fishing industry, and other wastes. Cottonseed meal, the by-product destined later to become the favorite base of nearly all tobacco mixtures, was first used on tobacco by R. E. Pinney of Suffield in 1877. Another vegetable meal, castor pomace, was introduced in the same decade but never became as popular as cottonseed meal. Of the other vegetable meals now in use, linseed meal was introduced about 1896 while soybean meal did not make its appearance until 1936 when it was first tried by the Tobacco Substation and soon found its way into many tobacco formulas. Many other vegetable by-products have been used to a less extent but none other than these four has established itself in the tobacco mixture.

Cottonhull ashes, another favorite constituent of the tobacco mixture for many years, first came into use in the 1870's, disappeared during the early decades of the present century, and was revived in the early 'thirties. A favorite formula 50 years ago was the Pinney formula, a mixture of cottonseed meal and cottonhull ash (with or without the addition of a little nitrate of soda).

Up to the time of the Civil War, farmers rarely grew more than five acres of tobacco on one farm and, since all farms had cows, horses and other animals, it was not difficult to fertilize the tobacco land largely with the manure produced on the farm, or at most, in the neighborhood. But with the acreage expansion and crop specialization that set in after the war, the tobacco farmer reduced his stock and enlarged his tobacco field until he could no longer fertilize it from his own stables. Stable manure was bulky and expensive to import from New York and other population centers, although this has been practiced to some extent even up to the present day. This situation stimulated the search for concentrated plant nutrients which were not so expensive to transport and was the stimulus for the growth of the chemical fertilizer business.

Probably the first straight chemical used here on tobacco was nitrate of soda, followed, as mentioned above, by superphosphate and the German manure salts. Many other chemicals, too numerous to list here, have been used and are still being included in the formula (See Table 1, page 32). Synthetic chemicals began with urea, introduced in 1926 and extensively tested by the Tobacco Substation during the following years.

Among tobacco dealers and manufacturers and, to a less extent, farmers, there has always been a strong prejudice, first, against the introduction of any new constituent in the tobacco formula and, particularly, against any material which is not natural organic matter. Johnson in 1872 writes that there was a prejudice against the use of fish scrap. It is said by old tobacco growers that cottonseed meal, just after its introduction, was violently opposed by the trade. There is probably no single ingredient in the formulas now used which has not had to earn its place against such opposition. These objections have been based on alleged impairment of quality or taste of the product, rather than reduction in yield or other measurable properties.

NITROGEN

Nitrogen is usually considered the most important element in tobacco nutrition in Connecticut because: (1) An acre of tobacco requires for its normal growth more pounds of nitrogen than any other food element except potash and calcium. (2) Nitrogen costs more than any other ingredient. More than half of the cost of a tobacco mixture is due to expensive nitrogen carriers. (3) The number of materials which may be used to supply the nitrogen is large; therefore, more consideration must be given to choosing the best nitrogen carriers. (4) Nitrogenous materials are subject to greater changes in composition and amount in the soil than are materials carrying other food elements. (5) Symptoms of nitrogen hunger are easily recognized by the grower. He knows well the damage to quality and yield if his nitrogen supply is short.

Functions

Protoplasm is the most essential part of the green plant; without it there can be no life nor growth. Nitrogen is one of the necessary chemical constituents of protoplasm. It enters into the composition of all proteids, the amino acids and amides which are in all parts of the plant. Nicotine, the alkaloid that is present only in tobacco and is responsible for a part of its peculiar properties, also contains nitrogen. Finally, the green chlorophyll is composed partly of nitrogen; break down of chlorophyll and consequent fading of the leaves is due to nitrogen deprivation.

In the cigar leaf a proper amount, distribution and balance between the various nitrogen compounds are essential for satisfactory color, grading and other qualities of the finished product. Too much

nitrogen stored up in the leaf, for instance, produces too dark colors and adverse smoking qualities; too little nitrogen results in harsh, non-elastic, poorly colored leaves of inferior quality.

Amount Absorbed

The total nitrogen in the leaf varies with the position on the stalk. The bottom leaves may contain between 1 and 2 per cent (dry weight basis), while up to 5 per cent may be found in the top leaves. Nitrogen is absorbed somewhat in proportion to available nitrogen present in the soil. The maximum absorption is reached in about 40 to 50 days after the plants are set out (68:167). The cured leaves from an acre of Havana Seed tobacco contain about 50 pounds of nitrogen (Conn. Sta. Bul. 180:7) but measurements of entire absorption including roots and tops raised this figure to 114 pounds (68:171).

Optimum Application

Although a tobacco crop uses 114 pounds of nitrogen per acre, extensive experiments (50:352) have shown that 200 pounds per acre must be applied, in order to allow for a reasonable amount of leaching and other losses. To be sure, yields increase with higher amounts applied, up to 300 pounds per acre, but the gain is offset by inferior grading (49:352).

Deficiency Symptoms

Nitrogen hunger in tobacco is first evidenced by the lower leaves taking on a pale green to yellowish color. The symptoms progress up the stalk and, in the absence of nitrogen, the entire plant becomes greenish yellow. The green vein pattern does not appear prominently as in the case of magnesium and manganese deficiencies. Growth is checked and the plants become stunted with the leaves narrow and pinched in proportion to the decreasing nitrogen supply in the soil. Nitrogen-starved cured leaves are canary yellow, non-elastic, brittle and almost worthless as cigar wrappers or binders.

Nitrogen Changes in the Soil

The tobacco plant absorbs nitrogen through its roots mostly in the form of nitrate or, under certain conditions, ammonia. But the nitrogen which we apply in the seed meals and other organics is not in nitrate form and, therefore, it is not readily absorbed by tobacco roots. The nitrogen in such organic materials is largely in protein or other complex compounds and, after it is distributed in the soil, is broken down by steps into amino compounds, ammonia compounds, nitrite and finally nitrate. Then it can be absorbed by the tobacco plant. This decomposition is accomplished by the action of different kinds of fungi and bacteria which inhabit the soil. The organic fertilizer materials, cottonseed meal, castor pomace, etc., differ among themselves in the rate at which they break down and furnish nitrate

to the soil. For example, cottonseed meal decomposes (furnishes nitrate) faster than corn gluten meal. In the order of rapidity of availability starting with the most rapid, the organics rank: cottonseed meal, linseed meal, fish, soybean oil meal, castor pomace, corn gluten meal (77:237).

Nitrate of soda, on the other hand, has all of its nitrogen in available condition just as soon as it is applied to the soil. Unfortunately, however, availability coincides with "leachability", i.e., nitrate is not only the most easily absorbed by the roots but it is also most easily washed out of the soil by heavy rains.

When the young plants are first set in the field, they need very little nitrogen. During the first 30 days in the field, an acre of tobacco needs only seven pounds of nitrogen (73:567). If a large proportion of the nitrogen is available during this period (as in nitrate of soda) it is in a precarious position and may easily be lost through heavy rains. The needs of the plants increase quite rapidly, however, after the first 30 days, reaching the maximum in about 60 days. An ideal nitrogenous fertilizer, then, is one which furnishes the nitrate very slowly in the early season but increases the supply more rapidly as the season advances. Toward the end of the growing season, demand should be in excess of supply in order to ripen the leaves and give the best quality of tobacco. It is thus a matter of supply and demand that ultimately measures the value of any fertilizer, i.e., the material with a time curve of availability most nearly matching the curve of the plants' increasing nutritional demands is the most efficient fertilizer. Year in and year out such a fertilizer will produce the best quality and yield of tobacco, i.e., has the highest crop-producing capacity.

In the following paragraphs the relative efficiency of different materials is discussed. "Relative efficiency" refers to the crop-producing capacity of a material when compared with cottonseed meal, and when used to furnish equal quantities of nitrogen (as determined chemically). Chemical analyses which show the percentages of nitrogen in the various materials, thus do not necessarily indicate the relative crop-producing capacities of these same materials.

Fertilizer Materials Containing Nitrogen

There is a considerable list of materials (carriers) which may be used to make up the nitrogen portion of the tobacco mixture. Usually a combination of several carriers is included. Theoretically, this would seem to be the best practice but field tests at the Experiment Station (47:78) failed to demonstrate any improvement in yield or grading by using multiple sources instead of a single nitrogen carrier. The nitrogen carriers are commonly classified into two groups: organic and inorganic (mineral). All commonly used tobacco fertilizer mixtures derive the major part of the nitrogen from organic sources. Long experience has shown that such a mixture produces the best qual-

ity tobacco and maintains the fertility of tobacco fields. Of the organic materials, the most commonly used are the vegetable meals, by-products of the extraction of vegetable oils. In addition to nitrogen, they also supply other food elements in smaller amount, a trait that may be an important reason for their popularity. Their rate of decomposition in the soil is another reason why they are so well-suited to the tobacco mixture.

Cottonseed Meal

Tobacco fertilization in Connecticut has been dependent on cottonseed meal as the main nitrogen carrier for more than two generations. Long experience and great satisfaction with this material has made it a "standard" with which results from newer sources of nitrogen may be compared. The balance between nitrogen and non-nitrogenous compounds (chiefly fibers) in cottonseed meal (81:99) may be one reason for its proper rate of liberation of available nitrogen.

Cottonseed meal contains about 6.5 per cent nitrogen. Only slightly more than half of this may be used by the crop or recovered (in nitrification tests, 81:99) although three quarters of the total nitrogen applied in the form of cottonseed meal may ultimately be liberated (lysimeter tests, 66:321).

Besides nitrogen, cottonseed meal contains smaller amounts of other plant foods such as potash (about 2 per cent) phosphoric acid (3 per cent) magnesium and calcium, also traces of boron (10-16 ppm) and possibly other minor elements.

Castor Pomace

This is another organic source of nitrogen, long in use as a fertilizer material in tobacco goods. Growers have considered it a second or even a last choice of nitrogen carriers, because frequently castor pomace was said to produce dark wrapper tobacco. This might have been true, when little was known about its performance in the soil. Recent studies (81:93-100 and 82:288-291) have indicated that castor pomace is fully comparable to cottonseed meal, if used on an "*efficiency*" basis. This means that 160 pounds of nitrogen in castor pomace will have the same crop-producing effect as 200 pounds of nitrogen in cottonseed meal. For farm practices, castor pomace may be substituted, pound for pound, for cottonseed meal. Handled in this manner, castor pomace will produce tobacco of the "stalk-cut" types fully comparable to other sources of nitrogen. In fertilization of Shade tobacco, at least a part of the nitrogen may be derived from castor pomace.

Linseed Meal

Linseed meal is an excellent source of nitrogen. Only the high price of this meal possibly prevents an extensive use of it, except for

fertilization of wrapper tobacco. When part of the nitrogen is taken from this source, a better "finish" of the wrapper leaf is obtained.

The rate of nitrification is similar to that of cottonseed meal but the material is slightly more "efficient" than the latter.

Soybean Oil Meal

This material is a more recently introduced nitrogen carrier (46:75). It contains more nitrogen than cottonseed meal (7.2 per cent), and a greater portion of the total nitrogen becomes available. In terms of efficiency, 170 to 180 pounds of nitrogen in soybean oil meal has the same crop-producing value as 200 pounds N in cottonseed meal. In addition, there is a somewhat better grading of tobacco through the use of the soybean product.

Used as a substitute for cottonseed meal, 1,600 pounds of soybean oil meal is as effective in nitrogen-supplying power as one ton of cottonseed meal (82:288). In extensive tests, some of which were in coöperation with commercial growers, soybean oil meal has produced very satisfactory grading of binder as well as of wrapper tobacco.

Dry Ground Fish

This by-product from fish oil factories and fish canneries has long been used in fertilization of Connecticut tobacco. Experiments and growers' experience have indicated that it is fully satisfactory. It is seldom or never used as a single source of nitrogen, but a few hundred pounds are commonly included in mixtures.

Dry ground fish contains 9 to 10 per cent nitrogen and about 7 per cent phosphoric acid (P_2O_5), with only about 1 per cent potash. Extensive tests have indicated that this material is "more efficient", i.e., more of its total nitrogen becomes available than that in cottonseed meal (73:568). The rate of nitrification is about the same as for linseed meal (77:236).

Corn Gluten Meal

When price and supply permit its inclusion as a fertilizer material, corn gluten meal may be used as a source of nitrogen. It contains about 6 per cent nitrogen and a little more than 1 per cent P_2O_5. Potash content is only about .6 per cent.

Limited experiments at this Station have indicated that the nitrogen is somewhat more available than in cottonseed meal (73:550 and 568). Yield figures surpassed those from cottonseed meal, while grading was somewhat lower than for the standard meal.

Sunflower Seed Meal

This material has been tried experimentally. From (unpublished) data on Shade tobacco it is indicated that this meal behaves

about the same as cottonseed meal in every respect. Due consideration, however, must be given to the fact that it contains more than 7 per cent nitrogen, on which basis the required amount of nitrogen should be calculated.

Carriers Not Derived from Plant or Animal Residues

This category includes materials of mineral nature and synthetic nitrogenous materials, which are being produced in ever-increasing quantities.

Nitrate of Soda

Although experiments (48:83) have shown that tobacco may be grown with nitrate of soda as the sole source of nitrogen, through fractional applications of the material, it is not practical to do so for various reasons. Furthermore, since Connecticut tobaccos are grown on light, sandy soils, prone to leaching, it is not common practice to include much, if any, nitrate of soda in the fertilizer mixtures.

There are, however, sections of the tobacco district with somewhat heavier soils. Here, nitrates may be used to supply 50 to 60 pounds of nitrogen to an acre. As a general rule for Connecticut, it is recommended that not more than one-fifth of the total nitrogen be supplied in nitrate form.

Nitrate of soda is of greatest use as a side dressing material, under conditions where it is necessary to replace available nitrogen quickly after excessive rains. Where the grower finds it convenient to apply the material by hand, 200 pounds of nitrate of soda per acre would be sufficient for one application.

If machinery is used, a bulky mixture must be employed, such as equal parts of cottonseed meal (or other oil meals) and nitrate of soda. This is applied at the rate of 300 to 400 pounds per acre. The side dressings are repeated if excessive rains occur again while tobacco can still be cultivated.

In an emergency it is sometimes necessary to add nitrate of soda when no further cultivation can be done. In such a case it is of importance to do this when the leaves are dry. (If the material is dissolved on the leaf, it will produce "burn-spots"). Nitrate of soda, applied this late in the season, is a reserve in case of further rains.

Sodium added through the use of nitrate of soda has never been observed to detract from yield, quality or potash content of tobacco, provided the crop has been furnished with proper amounts of potash and calcium. (See further under "Methods of application", page 37).

Urea and Uramon

Urea is the pure material made from synthetic ammonia and carbon dioxide. The product used as a fertilizer material contains about

46 per cent nitrogen. Uramon is the trade name for a more recently introduced form of urea. It has a light brown color, afforded by conditioning agents which make the material free-flowing and non-caking. Uramon contains 42 per cent nitrogen. The nitrogen in urea and uramon is 75 to 80 per cent available.

Extensive field experiments and lysimeter tests at this Station (16:230) have indicated that urea is about 20 per cent more efficient than cottonseed meal. This means that between 150 and 175 pounds of urea-nitrogen has a crop-producing capacity similar to 200 pounds of nitrogen in cottonseed meal. In years with a minimum of leaching rains, 150 pounds of nitrogen in urea produced yields and grading of tobacco fully comparable to those grown with cottonseed meal as the only source of nitrogen. Used on the basis of its higher availability, urea (uramon) may be substituted for cottonseed meal in *growing stalk cut tobacco.* In fertilizer mixtures, up to 200 pounds of urea (uramon) may be substituted for the common oil meal. *For primed tobacco* it is not advisable to use more than 50 to 100 pounds of urea in an acre-mixture. If urea is used in larger amounts, its unique availability will provide the early primings with a surplus of nitrogen.

Calcium Nitrate (nitrate of lime)

Calcium nitrate is an excellent source of quickly available nitrogen, containing 15 to 16 per cent of this element. The material is produced in large quantities in Europe but was off the market all through the recent world war.

Early experiments (31:379) with nitrate of lime in comparison with nitrate of soda indicated that the former product, possibly because of its calcium content, produced slightly higher yields than the standard material. The grading was about the same for the two materials.

Nitrate of lime should be used in the same way as nitrate of soda.

Sulfate of Ammonia

This has been found to be a good source of nitrogen for many kinds of crops. However, in a long series of experiments here (39:355) it gave uniformly poor results when used for tobacco. It makes the soil more acid, depletes the mineral bases, decreases the supply of phosphorus and increases soluble aluminum and manganese. All of these results are unfavorable to tobacco production. Even when neutralized by lime application, the cured leaves were found to be darker, thicker, more prominently veined and of poorer combustion. The results of all tests lead us to doubt whether sulfate of ammonia should ever be used in the tobacco mixture.

However, it may be used in a fall application to lower the reaction of a field with a soil that is too alkaline and therefore favorable to

black rootrot. Such applications should not be made in the spring previous to setting tobacco in the field.

Ammonium Nitrate

This material, containing 32 per cent of nitrogen, was put on the market in large quantities during the latter half of the second world war. Field tests started at that time show that it can be used profitably in a tobacco mixture to supply a part of the nitrogen. No adverse effects on the crop have been observed. Nitrogen from this source is easily leached out by heavy rains and, therefore, it should be used in much the same way as nitrate of soda.

Other Nitrogenous Materials Sometimes Used

Hoof and horn meal is a good source of nitrogen for tobacco mixtures and is used by some growers at the rate of 200 to 300 pounds to the acre. The supply is so limited, however, that it is rarely available. *Ammophos* is only rarely used for tobacco and there is a general belief that it is not as suitable as many of the other nitrogen carriers. No extensive field tests on which one could base a judgment have been recorded. The high content of phosphorus is unnecessary in building a tobacco formula and this may account for the fact that it has received so little consideration. *Nitrate of soda-potash* may be used in the same manner as nitrate of soda but does not come on the market in sufficient quantity any more to play much part in tobacco mixtures. Small percentages of nitrogen are also added incidentally in some materials that are included primarily for their content of other elements. Such are the *bone meals*, *tobacco stems*, etc.

PHOSPHORUS[1]

Functions

Phosphorus is essential in the formation of many protein substances in plants, some of which are the nucleoproteins in embryonic cells. Thus, its importance in reproductive organs and for maintenance of life itself is readily explained. It is also of great importance for proper and maximum root development. The relationship between nitrogen and phosphorus manifests itself in governing the maturity of plants in general and particularly of the leaf with respect to tobacco.

Amount Absorbed

At least .4 per cent phosphoric acid (P_2O_5) should be contained in the (air-dried) leaf for proper metabolic functions. Average

[1] *Phosphorus* (P), the chemical element, does not occur in nature in a free state but is always combined with other elements. In fertilizer analyses and literature, the percentage is expressed in terms of the pentoxide of phosphorus (P_2O_5) and commonly referred to as *phosphoric acid*. To convert figures for *phosphoric acid* to phosphorus, multiply by .44; the reverse may be accomplished by multiplying by 2.3.

P_2O_5 content of Havana Seed tobacco leaves grown on the Experiment Station farm was found to be .69 per cent (1:14). Irrespective of the abundance of available phosphorus in the soil, tobacco seldom absorbs more than 1 per cent P_2O_5 (air-dried basis). An *excess* of phosphorus in the soil has never been shown to affect growth adversely.

Signs of Deficiency

A tobacco plant deprived of available phosphorus shows, besides much stunted growth, leaves that are dark green, leathery and somewhat shiny. The leaf tends to become narrow at the base, thus giving it a somewhat spatulate shape. Observed from an oblique angle, the leaves appear to be a bronze color (52:401).

Optimum Amount to Apply

Soils vary in their supply of available phosphorus. It has been observed that old tobacco soils usually readily accumulate available phosphorus (1:15). The accumulation may be so great as to make unnecessary the addition of phosphorus to the fertilizer mixture for intervals of several years (1:8). This has lead to the general practice of applying fertilizers with a relatively low content of phosphoric acid (formulas, such as 6-3-6, 5-3-5 and 8-4-8). The amounts applied, together with ample supply of active soil phosphorus, are sufficient for proper nutrition and minimum fixation. An acre of tobacco removes only about 20 pounds P_2O_5, but a minimum of 120 pounds P_2O_5 per acre is generally advisable for several reasons (84:286).

Frequently, however, soils, especially those where tobacco has not been grown for many years, are found to be deficient in available phosphorus. When a soil test shows medium to very low content of phosphorus, the routine fertilization does not furnish sufficient amounts to cover both nutrition and fixation. In this case, the land should be limed, if necessary, and superphosphate, 16 to 20 per cent P_2O_5, at the rate of 500 to 400 pounds, respectively, per acre may be applied in the fall, or early in the spring, as soon as the land is plowed. This extra application of phosphates is designed to take care of a reasonable amount of phosphorus fixation, that is, to make combinations with active aluminum, iron or manganese usually present in our acid soils. Thus, the phosphoric acid supplied in the fertilizers may be reserved for nutrition.

Carriers

Bone phosphates, such as *precipitated bone*, *raw bone meal* and *steamed bone meal* are well-established sources of phosphorus. Recent experiments (84:283) have indicated that some new materials, *calcium metaphosphate* (if available on the market) and *triple superphosphate*, are satisfactory carriers of phosphorus.

The common grade of superphosphate (16 to 20 per cent P_2O_5) used as suggested above is employed for its merit of being water soluble, thus facilitating the reactions indicated. The bone phosphates (di- and tricalcium phosphates) are not water soluble and remain longer as calcium phosphates in the soil. This may explain the tendency of phosphorus accumulation through their continuous use.

POTASH

Functions

Potassium[1] is an essential element in the growth of all plants, its metabolic function being primarily that of an activating agent in the synthesis of carbohydrates and proteins. It also acts as a carrier in the absorption and translocation of other ions. There is some evidence that it makes the plants more resistant to disease. In tobacco it has three other specific functions: (1) It makes the plants more resistant to drought. (2) In the cured tobacco leaves, the potash salts absorb moisture and make the leaves pliable so that they can be handled during a "damp". (3) Potassium is the most important element in promoting the burning capacity of the leaves. Without potash, tobacco leaves have no fire-holding capacity at all; they would burn with a flame, like paper, but without the continuous incandescent combustion that is essential to cigar tobacco.

Amount Absorbed

Connecticut tobacco has a very high potash content, varying from about 4 to 8 per cent of the air-dried cured leaf (35:142). The crop takes from the soil more potash than any other nutrient—about 155 pounds to the acre in leaves and stalks. A small percentage of the potash is also leached out of the soil, especially during the months that the crop is not on the land. This loss is partly offset, however, by the liberation of a fraction of 1 per cent of the native potash in the soil. To replace these losses, heavy annual applications of potash are necessary.

Optimum Amount to Apply

Extensive field tests over a long series of years have demonstrated that, for average conditions, tobacco land should receive about 200 pounds of potash to the acre (35:173). Soil tests, however, may indicate some modification upward or downward, according to the determined supply of available potash already in the field.

Deficiency

Plants that are deficient in potash show distinctive symptoms unlike those of any other nutrient deficiency (35:140). The first symp-

[1] The chemical element *potassium* (K) does not occur in nature alone. In chemical and fertilizer analyses it is expressed in terms of the oxide (K_2O) commonly known as *potash*. Both terms are used here. All figures given are on the basis of percentage of K_2O in the dry weight of leaves.

tom is yellow mottling near the margins and tips of the leaves, somewhat resembling the early stages of ripening. The centers of the mottle spots next die and the surface of the leaf becomes "hobbly" or puckered. Very soon the margins and tips recurve downward giving a rim-bound appearance. Unlike magnesium hunger, the starvation symptoms of potash do not appear on the lowest leaves but are more often seen on the middle and upper leaves.

Excess

Excess of potash in the fertilizer should be avoided. Unlike some other salts, potash is absorbed directly in proportion to the amount in the soil solution, i.e., the tobacco plant has no selective capacity and excess amount in the soil is immediately reflected in high percentage in the leaves. Since all the potash salts used in the fertilizer mixture are very soluble, the salt concentration in the soil may become high enough to cause root burning. Increasing the application to 300 pounds caused a reduction in yield in a five-year test on the Station farm (35:184).

In the uptake of nutrients, potassium is antagonistic to the other base elements, calcium and magnesium. If the amount of potassium is increased, the other two bases are reduced in amount and may be insufficient for growth or optimum quality. Thus, too much potassium and not enough magnesium would cause a black ash and bad taste.

Carriers of Potash

A considerable number of materials have been used in the past and many are still used to supply the required amount of potash. Potash is practically completely soluble and available in all of those listed in Table 1; therefore, there is no problem of the relative availability of potash in the different carriers.

Cottonhull Ash

Cottonhull ash is probably the most commonly used carrier at present. The potash content varies considerably in different lots of the material but since it is sold on the unit basis, this involves no difficulty or uncertainty. There is an impression among tobacco handlers that cottonhull ash produces better quality of leaf than the other forms of potash. The potassium is largely in the carbonate form. In addition to potassium, cottonhull ash furnishes other beneficial elements, calcium, magnesium, phosphorus and smaller amounts of others such as boron which may augment its benefits. Cottonhull ash is basic but a test after five years of a maximum application did not show sufficient rise in reaction of the soil to cause deleterious effects.

Carbonate of Potash

Pure carbonate of potash is a very concentrated source of potash that has given good results but is not much used because of its high cost and its tendency to cake after absorbing moisture from the air.

Sulfate of Potash

This is more used than any other carrier except possibly cotton-hull ash, and all experiments show it to be a good source of potash. The sulfur in the sulfate ion is apparently not absorbed in sufficient quantity to influence the burn unfavorably.

Sulfate of Potash-Magnesia

This is a lower grade of potash but has been used to some extent especially where it is desirable to supply more magnesia.

Nitrate of Soda-Potash

Nitrate of soda-potash (nitropo) is a low grade South American product used more for its nitrogen than for the potash.

Nitrate of Potash

This is a good potash carrier and also contains 13 per cent of nitrogen. It contains nothing that could be deleterious to quality or growth. It was coming into general use before World War II but the supply was cut off during the war.

Tobacco Stems

Tobacco stems (midribs) are used by many growers and experiments have shown that there is no better potash carrier. Ground stems may be mixed with the other ingredients. Long stems (not ground) are applied separately to the fields.

Tobacco Stalks

These are quite similar in composition to stems and are commonly thrown back on the fields after the leaves are stripped off. Unless they are thoroughly plowed under and allowed to rot, they may carry the mosaic (calico) disease to the new crop.

Stable Manure

This material is the oldest source of potash for tobacco. Twenty loads (tons) of manure will provide all the potash necessary for an acre of tobacco.

Wood Ashes

Wood ashes furnish a variable percentage of potash and could be used but the supply is limited and they are not economical to handle. Moreover, the use of wood ashes in large amount involves the danger of making the soil too alkaline.

Muriate of Potash

This material should *never* be used because the chlorine in it ruins the burn of tobacco.

The small amounts of potash in all the organic meals are entirely available and can be added to the total in making up a formula.

CALCIUM

Functions

Calcium is one of the essential nutrient elements and is all-important because of its varied and vital functions. In the absence of calcium, the growing point (apex) as well as root tips fail to develop. Thus, this element is essential in formation of cell walls and particularly the middle lamella—the part that holds the cells together.

Calcium serves as a neutralizer of organic acids (of which the oxalic, citric and malic are most important) formed within the plant. Moreover, it plays an important part in translocation of nitrates within the plant (87:473) and possibly enters into composition of protoplasm and proteins.

In the cigar, calcium aids in giving a lighter color and better coherence to the ash and the cigar also will improve in taste with increasing content of calcium (78:254).

Amount Absorbed

Calcium is taken up by the plant partly in proportion to the available supply, partly guided by other bases that may retard the absorption (cation antagonism).

A minimum of 2 per cent calcium oxide (CaO) (in the cured leaf) is required (87:474) for normal growth. While the optimum amount of CaO centers around 5 per cent of the dry weight of the leaf, as much as 8 per cent has been found in tobacco.

Optimum Amount to Apply

Among the three bases, calcium, potassium and magnesium, calcium is most affected by leaching (64:397). It is, therefore, necessary to supply a tobacco crop with about the same amount of calcium as potash. Calcium is partly supplied by the various materials in the fertilizer formula and the balance may be added as lime or land plaster. However, on soils with ample amounts of available (replaceable) calcium this element needs no special attention (see "Interpretation of soil tests").

Deficiency Symptoms

Calcium deficiency symptoms seldom occur on tobacco in the field, although they have been observed occasionally. In the absence

of calcium, the terminal bud fails to develop and the tips of the youngest leaves shrivel up, turning brown or grayish. Sometimes the entire leaf is distorted (52:144). Should calcium deficiency occur in a field of tobacco early in the season (often the result of excessive rains), at least 500 pounds of lime per acre may be applied. A thorough soil test is advisable before another crop is planted on such a field.

Excess

Excess of calcium usually is the result of overliming. Also, on heavier soils there may be an accumulation of calcium through annual fertilization, especially if insufficient potash was furnished. Surplus calcium in the soil counteracts the uptake of potash and to some extent of magnesia (76:440). Moreover, an overlimed soil usually has a reaction (pH) that is conducive to black rootrot (pH 5.6 and higher, although on colder, heavier soil, black rootrot sometimes may occur at pH 5.3). A field containing an excess of calcium, concurrent with a pH-value that is considered too high for tobacco, may be improved by treating with sulfate of ammonia in the fall. In general, an application of 500 pounds per acre (without cover crops) will reduce the soil reaction by one half pH-unit. Results should be checked by a soil test the following spring.

Carriers

All lime materials contain calcium; the hydrated form, from 45 to 65 per cent CaO and the ground limestone, 30 to 45 per cent. Lime is usually employed to correct soil acidity. With the relatively small amount (an average of 500 pounds per acre) recommended for tobacco land, liming must be considered as furnishing an essential plant food, calcium, while the pH-value is used as a criterion. In the use of land plaster (gypsum, 32 per cent CaO), calcium is furnished in a neutral form, i.e., the soil reaction is not affected. Superphosphate and bone phosphates contain about 30 per cent CaO. In addition, most of the other materials used in fertilization of tobacco furnish small amounts of calcium, all of which should be taken into account in calculating the total amount of CaO in a formula.

At times, other calcium-carrying materials are available on the market, such as nitrate of lime and Cal-Nitro. Both of these contain about 27 per cent CaO, all of which is readily available.

MAGNESIUM[1]

Functions

Magnesium is essential to the growth of all green plants. It is one of the constituents of chlorophyll, the green coloring matter of

[1] The chemical element, *magnesium* (Mg), does not occur in a free state in nature but always in combination with other elements. In fertilizer and most chemical analyses, the percentage is expressed in terms of the oxide (MgO), *magnesia*. Both terms are used in this discussion but all analyses figures refer to MgO.

plants, and, when magnesium is lacking or in insufficient amount, disturbances in the formation of chlorophyll develop. The magnesium ion also functions as a carrier of phosphorus. It plays an important role in the formation of vegetable oils in the plant.

In addition to the above-mentioned functions, magnesium, in cigar leaf tobacco, has a special and important function in combustion of the leaf. If there is not enough magnesium, the cigar burns with a black ash, indicating incomplete combustion, and accompanied by unpleasant taste and aroma (86:469). The whiteness of the ash—and completeness of combustion of the carbon—increases directly in proportion to the percentage of magnesia in the leaf. In this special function, however, calcium may be substituted to some extent.

Amount Absorbed

The percentage of magnesia in the leaves is not at all constant, varying greatly according to the available supply in the soil. Plants may continue to live on a very small amount, but starvation symptoms (chlorosis) appear when the percentage of magnesia is reduced below .4 per cent (MgO) of the dry weight of the leaf. For good combustion, however, the leaves should contain 1.5 to 2.0 per cent (86:472). Leaf samples sometimes analyze above 4 per cent (86:472) but even a content of 2 per cent may result in a "flaky" ash, i.e., it loses its coherence and drops from the cigar during smoking (45:578).

Optimum Amount to Apply

Soils differ greatly in the natural supply of magnesia that they contain and therefore it is not possible to make a universal rule for magnesia application. A grower has two methods of deciding whether his field needs additional magnesia, (1) ash color and (2) soil test. If the cured tobacco leaf, rolled on a cigar, burns with too dark an ash, he should increase the magnesia in his fertilizer mixture. He may have his soil tested by the Experiment Station to see whether it is too low in magnesia. A general rule, based on field tests on the Experiment Station farm, is to apply 75 pounds of magnesia annually (44:581). In case a soil test has been made, a more accurate rule is to add enough in the fertilizer so that the sum of the determined native supply and the amount added in the fertilizer equals 100 pounds to the acre.

Deficiency Symptoms

Magnesia leaches from very sandy soils, especially during seasons of excessive rainfall. When the soil supply becomes so low that the roots cannot absorb enough to meet the physiological requirements of the plant (.4 per cent MgO), the leaves develop chlorotic symptoms known popularly as "sand drown". The color fades out between the veins to light yellow or almost white, contrasting strongly with the dark green pattern of the vein system. The leaves do not become

hobbly or recurved downward at the margins, as is the case in potash hunger, but remain smooth and feel thick and stiff between the fingers. The lower leaves are affected first but later the symptoms may travel up the plant, even to the top leaves in extreme cases. In very advanced stages, the yellow areas between the veins may die and turn brown. The most serious damage, however, comes from the checked growth of the plants and the lifeless character of the cured leaves (14:178).

If "sand drown" is observed early in the season, it may be remedied by applying 75 pounds of magnesia, preferably in magnesium sulfate, to the acre and working it into the soil.

It should be kept in mind that "sand drown" indicates *extremely* low magnesia. Many fields have enough magnesia to give the crop a normal green color but still not enough to produce tobacco of satisfactory burn.

Excess

Excess of magnesia should be avoided for two reasons: (1) It reduces the uptake of the other two important bases, potassium and calcium. (2) It may cause the ash to become "flaky" as previously mentioned.

Carriers

Magnesian lime or *ground limestone* (dolomite) are the cheapest and most used sources of magnesia in the fertilizer. These usually contain 20 to 30 per cent of MgO. Caustic or hydrated lime, however, should not be mixed with urea or ammoniacal compounds. When the test shows that the reaction of the soil is high, it is better to use some other carrier since all the forms of lime raise the soil reaction. It is better then to use *magnesium sulfate*. *Sulfate of potash magnesia* contains 10 to 12 per cent of magnesia and may be used. *Cottonhull ashes* contain 5 per cent. All of the organic meals have a small percentage of magnesia and should be considered in making up the formula. A ton of tobacco stems contains about 10 to 15 pounds of magnesia.

A comparison of magnesian lime, magnesian limestone and magnesium sulfate ("Emjeo") on a series of field tests (79:239) showed that all three of these carriers are satisfactory but that the absorption from sulfate was slightly higher than from the lime. From limestone it was a little lower than from hydrated lime.

BORON

Functions

While boron is fully as essential as any other plant food element, it has been termed a "minor" element. This, however, means

only that small quantities are required for normal plant growth. Its functions in the plant are not nearly as well known as those of most of the other elements, but research workers agree that the most important role of boron is confined to cell division. Boron is active in close association with calcium, which may be one reason why boron is easily fixed within the plant and a continuous supply from the soil is thus required.

There is some evidence (83:137-150) that boron interacts with nitrate and is a factor in the synthesis of organic compounds. These and perhaps other functions of boron possibly are involved in bringing about improvement in quality of tobacco when borax is applied to the soil (83:137-150, 89:5-8).

Amount Absorbed

The amount of boron found in the leaves is somewhat in proportion to the supply of active boron in the soil. Tobacco contains normally from .01 to .03 per cent boron oxide (B_2O_3) corresponding to 30 to 100 parts per million of the element boron (B). Plants may grow normally with considerably less than 30 ppm of boron in the (dried) leaf, and may reach as high as 150 ppm without injury to the crop.

Boron is absorbed in a certain ratio to calcium but, since the activity of this latter element is governed by the supply of potash, there is an interaction between the three elements. The ultimate deposit of calcium, potassium and boron in the leaf in appropriate amounts and interbalance is reflected in satisfactory grading and quality (89:5-8).

Optimum Amount to Apply

Although normal growth of tobacco occurs at a soil content of only .4 parts per million of boron (B), improvement in growth and quality results from increasing the content up to 4 ppm or somewhat higher, depending on how well the soil is buffered.

An important factor is also the content of available calcium, since it is indicated (89:5-8) that calcium and boron should be present in the soil in fairly definite proportions. The more (replaceable) calcium present, the higher would be the boron requirements.

Tobacco soils in general contain a limited amount of calcium, hence, if the land *is found to be lacking or insufficient in boron content* we need be concerned only with meeting the requirements of the latter element.

Carrier

Borax is a satisfactory and inexpensive carrier of boron (about 11.3 per cent B) and is applied at the rate of 10 to 20 pounds per acre, *depending on soil test* and *recommendations from your Experiment*

Station. The material may be mixed with the fertilizer at the rate of 5 pounds per ton for annual applications. One-time applications may be somewhat higher as conditions may indicate.

Deficiency Symptoms

In the absence of boron, the plant is dwarfed, with the growing point (apex) ceasing to develop. There may be an endeavor to start new shoots, the tips of which also fail to develop. The leaves become dark green, wrinkled and brittle. Roots will be poorly developed and brownish.

Definite boron deficiency symptoms, however, have not been observed in the field on Connecticut tobacco. Stages of poor growth, in connection with insufficient boron supply in the soil, have been observed.

Excess

An excess of boron causes injury to the plants, resulting in stunted growth or total failure. During the first world war, native sources of potash were used, some of which contained enough boron to cause injury to tobacco crops. At the present time, all the materials used for fertilizing tobacco hardly contain sufficient boron for replenishing the amount removed from the soil.

MANGANESE

Functions

Manganese is an essential plant food element. Although its functions are not fully understood, it is held that chlorophyll formation is dependent on the presence of manganese. With its activity of a catalytic nature, it stimulates oxidizing enzymes. It is also indicated (76:443) that it has a controlling action on calcium absorption and utilization of iron.

Amount Absorbed

From .01 to .2 per cent manganese (on dry weight basis) is found normally in tobacco, while only a few parts per million produce normal growth. In fact, only one half pound of active manganese (Mn) per acre need be present in the soil for proper plant growth.

Connecticut soils in general contain sufficient manganese (an average total Mn of 80 pounds per acre at plow depth). Tobacco grown on very acid soils may sometimes absorb undesirable amounts of manganese. A so-called "brick-colored" ash occurs on the cigar, if the leaf contains more than .05 per cent manganic oxide (Mn_2O_3). The brick-color increases in intensity with increasing content of manganese, provided the percentages of calcium and magnesium remain stable.

Deficiency Symptoms

Deficiency symptoms appear at first sight to be similar to those of magnesium hunger, but upon closer examination we find that the chlorosis is confined to leaves of the upper part of the plant (contrary to magnesium hunger). Also, the fine network of veins is more plainly outlined on the leaf. The root system is usually stunted, with an occasional lateral root of normal size. Under certain conditions, overliming may render manganese unavailable.

Excess

Excess uptake of manganese may cause injury to the plants. The injury or toxicity symptoms are associated with a high content of manganese in the leaf (.4 per cent Mn_2O_3). The toxic effects are shown by a yellowish green to sulfur yellow discoloring of the top leaves and buds. In this case the soil may contain as much as 160 pounds active manganese per acre, with a soil reaction below pH 4.5. A relatively heavy liming (not over one ton hydrated lime per acre) will remedy this condition.

The addition of a manganese carrier to the fertilizer mixture is not recommended.

ALUMINUM

Aluminum is found in most of the green plants but its essentiality for normal plant growth has never been established.

Tobacco contains on an average about .06 per cent aluminum (Al) on a dry weight basis. It is possible that it fills some function in conjunction with other (amphoteric) elements, such as iron, manganese, phosphorus and boron (83:137-150).

An *excess* of active aluminum in the soil may convert phosphorus to an unavailable form. Liming and application of superphosphate is recommended as a remedy. There is some evidence[1] that a high concentration of active aluminum, frequently found in "new" land is conducive to "black tobacco", a dark brown to bluish black discoloration of the cured leaf.

The most common *carrier* of aluminum is aluminum sulfate. A commercial grade of this material is sometimes used, at the rate of 500 to 1,000 pounds per acre, for acidifying the soil. This will lower the pH-value about one half unit depending on the buffer capacity of the soil (15:181-190).

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[1] S. B. LeCompte, Jr. Studies on black tobacco. Conn. Agr. Exp. Sta. Bul. 469; 130-155. 1943.

CHLORINE, SULFUR, SODIUM AND IRON

These four elements are always present in the plant, in the soil and in the fertilizer.

Chlorine

Chlorine is not an essential element in the growth of tobacco since plants can be grown to normal maturity in the complete absence of chlorine. To be sure, it may function physiologically as a carrier of other elements but, in cigar leaf tobacco, this function can be performed better by other materials. Of all elements, chlorine is the most damaging to the fire-holding capacity of the cured leaf. Even a very small percentage of chlorine (.4 per cent) in the leaf affects the burn adversely while a high percentage destroys the fire-holding capacity entirely (35:170). Chlorine is absorbed very readily by the tobacco plant. Therefore, it is important in mixing the fertilizer that the percentage of chlorine be kept as low as practicable. Materials containing high percentages of chlorine, such as muriate of potash, should never be used in a tobacco mixture. However, practically all of the materials used in making up a mixture contain small percentages (Table 1)—from a trace up to 2 per cent. Probably none of these in the amounts customarily used adds sufficient chlorine to influence the burn adversely. A ton of stable manure contains about 2 pounds of chlorine and a ton of poultry manure 3.4 pounds. This may account for the slightly inferior burn of tobacco where large quantities of chicken manure are used (25:105).

Only one chlorine salt has been found useful in growing cigar leaf. When seed beds are suffering from ammonia injury (Conn. Agr. Exp. Sta. Bul. 493:18), a treatment of the beds with a weak solution of calcium chloride neutralizes the ammonia in the soil and prevents further injury.

Sulfur

Sulfur, unlike chlorine, is essential for the growth of all plants. It is a necessary element in the composition of plant proteins and also seems to have some other functions that are not so well understood. Connecticut tobacco contains an average of about .5 per cent of sulfur (dry basis) (35:198). Only about .13 per cent is necessary for the normal development of the plant. The sulfate ion, like chloride, is detrimental to the fire-holding capacity of the leaf. It is fortunate, therefore, that the plant does not readily absorb larger amounts from the soil. It requires extremely large applications of sulfur in the fertilizer to raise the percentage of sulfur in the leaf to as high as 1 per cent (28:255). At the ordinary rates of application of our common mixtures, there is little danger of the sulfur content impairing the burn of the leaf. There is always enough sulfur in the soil and in the fertilizer so that it is not necessary to add any sulfur

purposely in making up a formula. Sulfate of potash and 20 per cent superphosphate contain large amounts of sulfur, while the organic meals and most of the other materials contain small quantities (Table 1). In general, a low sulfur compound is preferable to a high sulfur compound if there is an otherwise equal choice between the two.

Sodium

Sodium is always found in small quantity in tobacco (37:250, 63:389, 59 (1896):328) but is not essential to growth of the plant nor to best quality of the cured leaf (37:249). On the other hand, it does not appear to have any harmful effect (31:379, 37:250). Sodium content is usually less than .1 per cent (of the dry weight) but may be increased somewhat by heavy applications. The only material commonly used in a tobacco mixture which contains a high percentage of sodium is nitrate of soda, a very useful material both in the original mixture and particularly for side dressing and for top dressing seed beds. Its value, however, is not due to the sodium but to the very soluble nitrate with which it is combined. Nitrate of calcium is just as effective (37:249). In making up the formula, the percentage of sodium need not be considered.

Iron

Iron is necessary for the formation of chlorophyll and is found in small amount in tobacco as well as in all other green plants. Aside from its physiological function in the normal growth of the plant, it is not known to have any special effect on tobacco. All our soils contain enough iron to satisfy the need and it is not necessary to take it into consideration in tobacco fertilization. The percentage absorbed increases as the soil becomes more acid. Inadequate ration of iron causes the leaves to lose the green color but we have never seen this chlorosis in any tobacco field.

SOIL TESTING

In growing an expensive crop, such as Connecticut tobacco, it is worthwhile first to gather some essential facts about the land. A correct use of chemical soil tests will aid considerably in guiding proper liming and fertilization.

This, however, does not mean that all the land should be sampled every year. Land in good and satisfactory production need not be considered. Soil tests are of greatest value when:

1. The fertility and lime requirements (pH) are unknown, such as land new to tobacco.
2. Noticeable reduction in productiveness of the land has occurred.
3. The tobacco does not burn properly.

4. After heavy rainfalls during the growing season, it may be necessary to replace some of the nitrogen.

5. Used as a method of "trouble shooting", in diagnosing nutrient deficiencies (or infrequently, excesses) of the crop. Other crop maladies may be revealed also.

When and How to Sample the Soil

The most suitable time to secure soil samples is in the autumn, after the crop has been removed, because then the grower has had the opportunity to observe the growth of his crop and is now able to decide what fields did not produce according to expectations. Careful planning also includes sampling of land that has been "rested", newly broken-up land, or fields used for other crops, but intended for tobacco the following season.

Spring sampling should be considered only as an emergency, e.g., when the grower, for one reason or another, was unable to sample the soil the previous fall, or desires a check-up on a soil treatment (such as application of sulfate of ammonia, superphosphate, liming or manuring).

With an auger or a trowel one should take about 20 samples of soil to a depth of about six inches from a uniform area (one or several acres). The soil is collected in a clean pail and thoroughly mixed. About a pint of the mixture is transferred to a clean paper box (an ice cream carton is excellent) or strong paper bag, which should be *numbered.* The grower keeps a record of the samples for proper identification later. If part of a field differs from the general area, a separate sampling should be made. Sampling should not be undertaken when the land is muddy or extremely dry.

In sampling a spot of land during the growing season, where growth is abnormal, or for the purpose of finding out whether side dressing is needed after excessive rainfalls, the borings (or slices) should be taken between the plants in the row.

The samples should be brought or sent to the Tobacco Substation in Windsor, accompanied by full information as to *the purpose of* testing.

Interpretation of Soil Test

The pH tests indicate the degree of acidity (Connecticut tobacco land seldom is neutral or alkaline). Tests showing

below 4.2 – extremely acid
4.3 – 4.9 – very acid
5.0 – 5.6 – moderately acid
5.7 – 6.0 – acid
6.1 – 6.8 – mildly acid
6.9 – 7.2 – neutral

Moderately acid soils (pH 5.0 to 5.6) are best suited for Connecticut tobacco. Higher reactions are to be avoided because they favor the development of black rootrot. Rootrot resistant strains do well even with reactions above pH 6.0.

pH-values, together with the determined content of calcium and magnesium, are used as a guide for liming. The test for calcium is satisfactory when it registers low (L) or above. For magnesium, it should be medium high (MH) or higher. A soil in this situation with pH test 5.0 or above needs no addition of lime.

With pH-values between 4.9 and 5.2, usually corresponding to very low calcium and moderate content of magnesium, 500 pounds of hydrated magnesium lime per acre may be applied after plowing the land.

When pH tests are below 4.9 but above 4.3, 600 to 700 pounds of hydrated magnesian lime per acre should be applied.

Finely ground magnesian limestone (dolomite), at the rate of 800 to 1,000 pounds per acre may be applied to land with pH-values below 4.3. This relatively great amount may be plowed under.

Micro-chemical tests are made according to the Universal Soil Testing System[1] and the results are given by letter symbols: EL = extra low, L = low, M = medium, MH = medium high, H = high, VH = very high, EH = extra high. An adaptation of the tests with respect to tobacco is given here.

Nitrate Nitrogen

This type of nitrogen is immediately available to plant growth. During the growing season, a test of medium high (MH) and higher is satisfactory. A fair amount of nitrate shown in a spring test indicates a retentive soil, while excessive nitrate in the fall suggests over-fertilization of nitrogen.

Ammonia Nitrogen

This material changes rather quickly in the soil into nitrates. High tests are shown from one to three weeks after fertilization. The test is useful in estimating available nitrogen in soils after excessive rains, in conjunction with the nitrate test.

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[1] Conn. Agr. Exp. Sta. Bul. 450. 1941.

Phosphorus

The phosphorus content shown in the test is readily available to plants. A medium high (MH) content, and higher is satisfactory. (For further interpretation of this test see under "Phosphorus", page 14.)

Potassium

This element is readily available. A test showing medium (M) or lower content means that a tobacco crop would hardly receive sufficient potash with routine fertilization for proper burning qualities, unless the season was very favorable, i.e., ample moisture, but not too wet. By applying tobacco stems or stalks, the potash level is easily raised. It may also be improved by adding more potash material in the fertilizer or directly to the land.

An extra high (EH) potassium test indicates an abundance of available potash. If the grower uses home mixed fertilizer, a saving in potash material may be made, since only 175 to 180 pounds potash (K_2O) per acre would be required, provided most of the land runs uniformly high in this plant food.

Calcium

Calcium, also, is readily available. It has a stabilizing effect on soil acids and nitrates produced from the organics supplied in fertilizers. A very low (VL) test indicates insufficient amount and lime should be applied according to pH test (page 29). On very sandy soils, the pH-values may be satisfactory, yet the calcium content very low to nil. In these cases, landplaster should be applied at the rate of 300 to 500 pounds per acre, depending on the severity of the demand.

At times, the magnesium content may be high (H) or very high (VH) but calcium and pH very low (below 5.2). Under these conditions, it is recommended that *calcic hydrated lime* be used; this furnishes a minimum amount of magnesia. Use the same quantities as suggested for other lime materials in accordance with pH-tests.

Magnesium

As shown by the test, magnesium is readily available. A medium high (MH) test is satisfactory. If magnesium is below requirements, but with suitable pH and calcium content, 200 pounds of magnesium limestone per acre may be added in home mixed fertilizer or 300 to 400 pounds (the smallest amount which can be applied with a sower) per acre, applied directly to the land. The latter quantity will not materially increase soil reaction (if not above pH 5.5).

Minor Elements

Minor elements such as aluminum, manganese, iron and boron are determined on special request. These tests are of special diagnostic value in examining plant food deficiencies or excesses.

Finally, it must be emphasized that the results from the tests are only estimates, but they are *reliable to the degree to which they truly represent the parcels or lots of land, for which information is requested.*

FIGURING FORMULAS

In the preceding pages, plant food and fertilizer materials that may be used in raising tobacco have been discussed. It was learned that the crop on an acre of average soil requires 200 pounds of nitrogen (N), a minimum of 120 pounds of phosphoric acid (P_2O_5) and about 200 pounds of potash (K_2O). Liming materials supply calcium and magnesium, in addition to small amounts present in various fertilizer materials.

In Table 1 average analyses of materials commonly used in tobacco fertilizers are listed. Numerous combinations may be made, but the composition, shown on page 33, on an acre basis is given as an example.

In the above formula, neither the combination nor the number of materials should be considered essential or "ideal", because good tobacco may be raised with fewer materials or other combinations, as long as the needed amount of plant food is satisfied.

In examining how the various materials furnish their part in the formula, we learn from the reference table that cottonseed meal contains 6.5 per cent nitrogen (N), 3 per cent phosphoric acid (P_2O_5), 2 per cent potash (K_2O), and so on.

The percentage of plant food is multiplied by the number of pounds of material used and the product is carried out into the proper column. Thus, 1,800 pounds of cottonseed meal with 6.5 per cent nitrogen (N) furnished 117 pounds toward the total of 200 required. The same procedure is followed for the other constituents and materials.

On the other hand, if it is desired to include a certain amount of plant food in the formula, such as 100 pounds of nitrogen from cottonseed meal, the procedure is reversed. The 100 pounds of nitrogen is divided by the percentage, .065, and we find that it takes about 1,500 pounds of cottonseed meal to provide the amount.

Table 1. Average Analyses of Materials Which May be Used in Tobacco Fertilization.

Compiled by Tobacco Substation in Windsor, Conn.

Name of materials	Percentage of nutrients						
	Nitogen N	Phosphoric acid P_2O_5	Potash K_2O	Calcium CaO	Magnesia MgO	Sulfur SO_3	Chlorine Cl
Ammonium nitrate	32.5	...	...	...	...	...	...
Ammophos A	11	48	...	1.8	.6	6.5	.03
" B	16.5	20	...	.4	.3	38.5	Trace
Bone meal (raw)	3.5	24	...	31	.8	.6	.2
" " (steamed)	2.5	23	...	33	.4	.3	.07
Bone, precipitated	...	40	...	30	.5	3.4	1.2
Cal-nitro	16	...	...	27	.13	...	...
" " (dolomitic)	20.5	...	...	11.4	7.4	...	None
Carbonate of potash	...	...	64	.2	None	.6	.4
Castor pomace	5.5	2	1	1	1	...	...
Corn gluten meal	6	1.3	.6	...	.6	...	...
Cottonseed meal	6.5	3	2	.3	.7	.5	.04
Cottonhull ash	...	3	25-40	11	5	2.5	1.5
Dry ground fish	9	7	1.1	8.6	.4	4.6	.45
Emjeo (magnesium sulfate)	...	...	...	3	30	66	...
Horn and hoof meal	15	...	...	2.7	.2	1.8	...
Kieserite (magnesium sulfate)	...	...	...	.6	32	64	.02
Landplaster	...	...	...	32	.7	43	Trace–.3
Lime, hydrated (high calcium)	...	...	...	65	1.5	...	...
" " (" magnesia)	...	...	...	45	27	...	...
Limestone (high calcium)	...	...	...	44	5.6	.1	Trace
" (" magnesia)	...	...	...	30	20	...	...
Linseed meal	6	2	1	.6	.8	.9	.07
Manure, cow (fresh)	.5	.3	.5	.2	.1	.1	.1
" , horse (fresh)	.6	.7	.4	.5	.2	.1	.1
" , poultry (fresh)	1	1.3	.5	1.6	.3	...	.17
Nitrate of lime	15	...	...	27	2.5	.05	.17
Nitrate of potash	13	...	44	.6	.4	.7	1.1
Nitrate of soda (Chilean)	16	...	...	.2	.2	.2	.6
" " " (synthetic American)	16	...	...	.1	.06	.2	.2
Nitrate of soda-potash	14	...	14	.2	.16	.07	.5
Peruvian guano	16	10.8	2.7	11	.9	3.6	1.9
Soybean oil meal	7.2	1.6	2.5	.6	.6	.3	.03
Sulfate of ammonia	20.5	...	...	None	None	58.7	.8
Sulfate of potash (European)	...	...	48	.5	1	43.5	2.1
" " " (American)	...	...	50	...	...	47	...
Sulfate of potash-magnesia	...	...	25	2	11	46	2
Sunflower seed meal	7.7	2.3	2	...	.9	...	...
Superphosphate (low grade)	...	20	...	27	.5	29	.3
" , triple	...	47	...	30	...	...	...
Tobacco stems, ground	1.3	.7	5-7	5-10	.6	1	1.2
" " , long	2.5	.7	6	5	.6	1.2	...
Tobacco stalks, ground	3.4	.8	4.6	...	...	...	...
Urea (European)	46	...	...	...	...	...	...
" (Uramon)	42	...	...	...	...	...	...
Wood ashes	...	...	4-6	28-36	3.5	1	.5

Example of Fertilizer Formula

Pounds of material per acre	Name of materials	Pounds nutrients per acre					Equiv. acidity (A) and basicity (B)	
		Nitrogen	Phosphoric acid	Potash	Calcium	Magnesia		
		N	P_2O_5	K_2O	CaO	MgO	A	B
1,800	Cottonseed meal	117	54	36	5	13	180	
500	Castor pomace	33[1]	10	5	..	4	30	
200	Dry ground fish	18	14	..	..	..	10	
100	Ammonium nitrate	32	..	..	..	..	59	
200	Precipitated bone	..	80	..	60	..		50
200	Cottonhull ash (30%)	..	6	60	22	10		112
200	Sulfate of potash (American)	..	..	100	..	..	Neutral	
100	Dolomite	..	..	..	30	20		100
200	Landplaster	..	..	..	64	..	Neutral	
3,500	Total	200	164	201	181	47	279	262

[1] Note: The nitrogen in castor pomace is calculated on "efficiency" basis, i. e., considered containing as much nitrogen as cottonseed meal. See page 10 for details on this point.

Converting to Ton Basis

If it is necessary to convert the quantities used in the formula, discussed above, to a ton basis, the following rapid calculation may be made:

Multiply the number of pounds of each material in the acre formula by 2,000 and divide by the total pounds of the mixture. For example: 1,800 CSM x 2,000/3,500 = 1,028.

Thus, we obtain:

1,028	pounds	Cottonseed meal
290	"	Castor pomace
114	"	Dry ground fish
56	"	Ammonium nitrate
114	"	Precipitated bone
114	"	Cottonhull ash
114	"	Sulfate of potash
56	"	Dolomite
114	"	Landplaster
2,000	pounds	

The figures will be rounded out somewhat, since a 3 per cent over-run is desirable to compensate for loss in mixing and weighing.

Table 2. Equivalent Acidity and Basicity of Some Fertilizer Materials

Acid-forming and basic fertilizer materials	Pounds lime ($CaCO_3$) for 100 pounds of product	
	Required A (acid)	Equal to B (basic)
Ammonium nitrate	59	
Ammophos A (11-48)	55	
" B (16-20)	88	
Bone, precipitated		25
" , raw		25
" , steamed		25
Cal-nitro (16% N)		19
" , (dolomitic) (20.5% N)	Neutral	
Carbonate of potash		75
Castor pomace	6	
Cottonseed meal	10	
Cottonhull ash		56
Cyanamid		63
Dry ground fish	8	
Landplaster	Neutral	
Limestone (dolomite)		100
" (calcic)		90
Nitrate of lime		20
Nitrate of soda		29
Nitrate of soda-potash		25
Nitrate of potash		25
Peruvian guano	13	
Sulfates (all)	Neutral	
Superphosphates (all)	Neutral	
Tobacco stems		12
Urea (Uramon)	75	

Acid-base Balance of Fertilizer

The different fertilizer materials added to the land in mixtures or separately may have a neutral, acid or alkaline effect on the soil. The oil meals and other organics produce a certain amount of acidity, while it is commonly known that ashes and lime tend to "sweeten" the soil.

In recent years, much work has been done on the effect of fertilizer materials on reaction of soils. In Table 2, the estimated amount of acidity or basicity is given for various materials. It is found, for instance, that 100 pounds of cottonseed meal has an equivalent of 10 pounds "acidity", which means that 10 pounds of calcium carbonate (limestone) is required to neutralize the acidity produced.

Going back to the sample formula (page 33), we find in the last two columns the calculated acidity and basicity resulting from the different materials. With 10 pounds of lime wanting for each 100 pounds of cottonseed meal included, we obtain 180 carried to column "A". The procedure is the same for the other acid-forming materials. The values for materials with alkaline tendency are carried to column "B". Sulfate of potash and landplaster are examples of "neutral" materials, that is, they do not affect the soil in either direction.

The total of acidity that will result is weighted against the expected total basicity. If both reach about the same magnitude, the fertilizer mixture is neutral in its effect on the soil.

Acid-forming fertilizers are obtained by reducing or omitting materials of alkaline tendency. Conversely, fertilizers that will "sweeten" the soil are produced by adding lime in excess of neutrality requirements.

Slight changes in soil reaction may be brought about by using the latter two types of fertilizers. If more substantial changes are required, separate applications of lime must be made to increase the pH-value, and of sulfate of ammonia to lower it.

MIXING THE FERTILIZER

After having decided on the formula which he believes is most suitable for his needs, the grower has four choices for getting his fertilizer mixed and ready for application.

1. He may purchase a standard brand of mixture, of which many good ones are sold by reliable dealers.

2. He may turn over his desired formula to a commercial fertilizer mixer and dealer to be compounded according to his directions. Usually, the commercial mixer also sells him the separate ingredients.

3. He may own a power mixing outfit where he can use his own labor. This is a method commonly used by the growers of large

acreages, or by several growers collectively. They purchase their own ingredients wherever they can get the best prices.

4. He may purchase his own ingredients and mix by hand without any special equipment. This method is employed by many growers of small acreages.

The grower naturally tends to select the method that is most economical in his particular circumstances. The use of a standard brand is subject to the objection that it is the least flexible, least easy to adapt to the special needs of particular fields or farms. This objection may frequently be overcome by applying additional materials separately. When there is a shortage of labor on the farm, it is often economical to purchase standard brands or to have the formula mixed by a commercial mixer. On many farms, however, there is a surplus of labor during slack times of the year or periods of inclement weather—labor that must be paid for, idle or busy. In such cases, it is commonly more economical for the grower to purchase his ingredients separately, mix and bag them on the farm. Whether or not he should purchase a small mechanical mixing outfit for this purpose depends on the size of his operations. There has been a great increase in the number of such outfits owned by individual farmers, firms or combinations of growers.

Hand Mixing

For this task, no equipment is needed except such as is found on any farm—a few shovels, a level floor in the barn or shed, and a platform scale.

The following very simple plan of procedure will give just as good a mixture as can be obtained in a commercial mix.

1. Select materials to be used and calculate the amount of each needed for each acre (as discussed on page 31).

2. Mix in acre batches. Except for the more concentrated materials, bags need not be split.

3. Spread the material used in the largest amount (usually the seed meal) in a layer not over a foot deep on the floor. Spread the other ingredients, one at a time, in successive thin layers on top of the first.

4. Start at one side and shovel all into a pile on the other end of the floor, shovelling from the bottom of the old pile and throwing on the top of the new pile. In the same way, mix further by moving the pile two or three times from one side of the floor to the other until the mixture is uniform in color.

5. If necessary, use a coarse screen (set at an incline like a sand screen) to separate lumps for crushing. If all the mixture is thrown

through the screen in the last move of the pile, it will improve mixing.

6. Bag mixed fertilizer with the same weight in each bag to facilitate uniform application on the field.

METHODS OF APPLICATION

The usual method of fertilizing is to distribute the entire required amount of the mixture with a fertilizer sower on the field after it has been plowed and harrowed. It is next thoroughly mixed with the top soil by a disc harrow. It has long been considered the best practice to apply the fertilizer a week or two before the plants are to be set, because this allows time for the organics to be partly converted into available nutrients and also it might allow the soluble salts to become better diffused and less likely to cause root burning. Actually, an extensive five-year field test (26:100) showed that it made no difference in yield or quality whether the fertilizer was spread a week or two before setting or on the same day the plants were set. In fact, fertilizing before setting involves the risk of losing some of the soluble nutrients by leaching if heavy rains come during the interval. Convenience with respect to his other work may just as well be the grower's guide for timing the application.

Many growers believe it is better not to apply all the fertilizer before setting the plants. They prefer to apply a part of it later as a side dressing to the growing plants. To determine the relative value of the two systems, field tests were conducted over a long series of years at the Tobacco Substation. Results, varying from year to year, showed that:

1. In dry years or those without leaching rains, it is better to apply all the fertilizer at one time, in advance of setting.

2. During years of heavy leaching rains, better results are obtained by reserving a portion of the fertilizer for later application to the growing plants. Several later applications are preferable to one.

3. Later application rations should consist mostly of quickly available nitrates and should be made *immediately* after heavy rains without waiting to see how much the crop is going to suffer.

4. Coarse sandy soils with porous subsoils show greatest benefit from fractional applications.

From these results, it is evident that the relative value of the two methods depends on the character of the growing season, i.e., the amount and distribution of rainfall.

Since, at the time of making the initial application, it is not possible to predict the season's rainfall, the safest rule is: Apply at the start the standard amount needed for growing the crop. As often as

heavy leaching rains occur after the crop is growing, apply *additional* nitrogen to replace that which has leached out.

Thirty to 40 pounds of nitrogen to the acre is the maximum quantity that should be applied as a side dressing. The usual practice is to mix 150 to 200 pounds of nitrate of soda per acre with an equal amount of cottonseed meal or other organic diluent in order to facilitate distribution. Wheelbarrow sowers, hand or tractor drawn, are usually employed for distribution. If spread by hand, the nitrate need not be diluted with organic meals. In exceptional cases, a soil test may show that some element other than nitrogen, is low and then this may be added to the mixture. Such cases are rare, however, and should be treated only on recommendation.

The relative merits of distributing the fertilizer equally in all of the soil surface and of concentrating it in bands on both sides of the row was measured by a five-year test at the Tobacco Substation (20:269) with the following results:

1. There was no significant difference in yield.

2. Grading of the cured tobacco was somewhat better with band application.

3. During very dry years, many of the plants in the band application plots died or started very slowly on account of excessive concentration of fertilizer salts.

The risk of loss from fertilizer burn makes band application an uncertain and questionable practice under the conditions of this experiment. A few growers sow a small part of the fertilizer "in the mark" before setting and consider that they get a quicker start and better crop in this way. A similar effect may be obtained by using a weak "starter" solution in the setter barrel, for example, two or three pounds of nitrate of soda to 50 gallons of water.

Spreading the fertilizer on the land before plowing, as a means of getting it deeper in the soil, has also been tested at the Tobacco Station (27:103). This method did not increase either the yield or the grading of the tobacco but gave just as good results as the customary method. In a dry year, however, it was found that a more uniform stand of plants, with less restocking, was obtained where the fertilizer was plowed under.

ANIMAL MANURES

Stable manure was probably the first fertilizer used in growing tobacco in Connecticut in colonial days and was the mainstay of the growers for over two centuries. It was only after the farmers began to specialize and devote the greater part of their acreage to tobacco and, therefore, did not have enough manure on the farm to fertilize their increased acreage, that commercial mixtures came into use.

Manure is still used on many farms as a supplement to the commercial fertilizer but very few farmers use manure alone for growing the crop.

Stable manure contains all of the nutrients needed for a crop of tobacco. Moreover, as indicated in the analyses on page 32, these elements are in somewhat the same proportion as they are in a good tobacco mixture. Thus, horse manure corresponds in ratio of food elements to a 5-3-5 fertilizer in nitrogen, phosphorus and potash and also has sufficient calcium, magnesium and minor elements to satisfy the needs of the tobacco plant. Twenty tons of fresh horse manure supply the same quantity of nitrogen, phosphorus and potash as two tons of a 5-3-5 mixture. Moreover, stable manure adds to the humus content of the soil (36:233), improving its physical condition, and increases its capacity for retaining water (33:387) and nutrient elements.

There are, however, certain objections to the use of manure:

1. It is much more expensive than commercial fertilizer if one has to purchase it and involves more labor in transportation and application. If one has a supply on the farm and uses it to supplement the commercial application, however, this objection is largely overcome.

2. The use of manure makes the land more favorable to the development of the fungous disease, black rootrot. Thus, in field tests where manure was applied annually (33:384) the yield began to decline the third year and at the end of five years the crop was almost a failure. This objection may be overcome, however, by growing strains which are resistant to rootrot—such as Havana Seed No. 211, Connecticut Shade 15, etc.

In crop-producing capacity, a pound of nitrogen in manure is not equal to a pound in the usual commercial mixture—at least not in the first year. In the first place, some of the nitrogenous compounds in manure decompose too slowly to come into an available condition during the first growing season. In the second place, a considerable part of the nitrogen is used to nourish the soil organisms that decompose the straw or other high-carbon-low-nitrogen ingredients of stable manure. In the course of time, all of this nitrogen comes into an available condition. Some of it is leached out of the soil during the part of the year when the land is not occupied by the tobacco crop. Another part of the nitrogen and other elements become available to tobacco crops of the following years and thus are not wasted. Thus, in field tests (17:242) it was shown on plots previously manured for 10 years that, the first year manure was omitted, the crop showed a gain of 25 per cent in yield and 33 per cent in grading when fertilized just like the other (not manured) parts of the field. This residual effect from previous application of manure was still apparent the second year after manure applications were omitted and increased the yield by 7 per cent.

The puzzling questions often asked are: How may we calculate the crop-producing value of the nitrogen in manure? How much may we reduce the commercial dose if we have manured the land? Potash and phosphorus in manure are probably equal pound for pound to the same elements in the commercial mixture and may, therefore, be reduced to the same extent as they are supplied in manure. The value of the nitrogen, for reasons explained above, is so variable, depending on the amount of straw, rate and state of decomposition, character of the season and other factors, that no fixed value, or rate of substitution can be accurately assigned. As a rough estimate, it is customary to calculate the value at about 50 per cent of the nitrogen in the manure, e.g., if 10 tons of manure (containing 100 pounds of nitrogen) have been spread on an acre, one may safely reduce the nitrogen in the commercial mixture by 50 pounds. Some(unpublished) field tests and the experience of many growers support this estimate.

Poultry Manure

Due to great increases in the extent of the poultry industry in Connecticut in recent years, this type of manure has become abundant locally. It offers a possible material for tobacco fertilization. It contains twice as much nitrogen (analyses in Table 1) as the average stable manure and contains substantial percentages of the other necessary elements. There have been very few carefully conducted field tests to establish its value for tobacco. In a test (25:105) at the Experiment Station, however, 10 tons of poultry manure, reinforced with 300 pounds of cottonhull ash to equalize the potash, were compared with a standard tobacco mixture. Both in yield and quality the tobacco grown on poultry manure was as good as that on the standard. The only objection noted was a slight reduction in fire-holding capacity. This difference was not of sufficient magnitude, however, to rule out the use of poultry manure.

FERTILIZING THE SEEDBED

The Connecticut grower does not ordinarily change the location of his seedbeds from year to year, as is the custom in many tobacco sections. When he has found a suitable site with respect to slope, drainage, weather barriers, soil characteristics and moisture, at a convenient distance from his house and tobacco lots, he usually installs permanent side boards and a water supply with well, pump or reservoir tank, faucets, etc. It would be too expensive to move all this equipment each year and, moreover, experience has shown that, with proper care, there is no need of changing.

The constant removal of thousands of seedlings with their roots and adhering soil from a small area of soil depletes it rather thoroughly of nutrient elements. The seedbed is as completely robbed of its plant food every year as is the field where the crop is grown to maturity. Moreover, the seedling roots do not forage as deeply in

the soil as field plants and it is essential to have an adequate food supply in the layer close to the surface.

Despite this heavy requirement of the seedlings, it has been the experience of the writers, that vastly more harm is caused each year by *over*-fertilization than by *under*-fertilization of the beds. Roots of the tiny germinating seedlings are very easily injured by too high concentration of fertilizer salts or ammonia in the soil. Many bed failures or partial failures are traceable to such fertilizer "burn". We have never seen tobacco plants die from too little fertilizer, although the rate of growth may be slowed.

The actual nutrient requirement of the seedbed is essentially the same as for the field. No special mixtures or mysterious formulas are needed. The main difference is in the *time* of application.

Many successful growers use no fertilizer—or at most a very light application—when fitting the bed soil for seeding in the spring. The fertilizer is applied either during the previous summer and fall or after the plants have germinated and started to grow. An excellent and commonly practiced plan is to cover the beds with a heavy coat of stable manure after the pulling season is over. This may be left on the surface until fall—or even spring—or may be plowed under at any convenient time in the summer. It will be pretty thoroughly rotted before time to seed the beds the next spring. Some prefer to supplement this by an application of regular tobacco mixture or of cottonseed meal alone in the fall, but the manure alone is sufficient. If a regular tobacco mixture or cottonseed meal is used instead of manure, or as a supplement, it should not exceed one-half to three-quarters of a pound to a square yard of bed. In some cases the growing seedlings may later show symptoms of nitrogen or potash starvation in the spring. If the difficulty is nitrogen starvation, this may be remedied by soaking the beds with nitrate of soda solution made by dissolving two to three pounds of nitrate in a barrel of water: the same amount of nitrate of potash may be applied if the trouble is potash starvation. A gallon of the solution to a sash should be sufficient. The solution should be washed off the leaves by sprinkling with water after treatment. Top dressings are also made sometimes with fish meal, "Swiftsure", "Vigoro", etc.

It is a common practice to add shredded humus or black swamp soil, covering the surface with a one-inch layer and then working it into the top soil. This excellent practice improves the mechanical condition of the soil and is beneficial, but it adds very little plant food.

Ammonia injury, from too much ammonia in the soil, is a very common cause of bed failures. This is most often caused from seeding too soon after the beds are steamed. If considerable nitrogenous fertilizer (fish, organic meals, manure, etc.) has been added to the soil, the steaming frees the ammonia and also kills most of the nitrify-

ing bacteria which are necessary to convert the ammonia to nitrate. The net result is an accumulation of ammonia in the soil. Germinating seedlings are very sensitive and easily killed by ammonia. Two measures to avoid this are recommended: (1) Don't overfertilize with nitrogenous materials. (2) Wait at least ten days after steaming before seeding the beds.

When it is found that the plants are dying from ammonia injury, the trouble may be alleviated by soaking the soil with calcium chloride solution made by adding two or three pounds of calcium chloride to a barrel of water. Apply one gallon of solution to a sash.

RELATION OF COVER CROPS TO SOIL FERTILITY

The tobacco crop occupies the land for a period of only 70 to 90 days—less than one-fourth of the year. It is now the general practice to sow a cereal crop on the land, just as soon as the tobacco is harvested in late summer and thus keep the ground covered by vegetation through the fall, winter and spring until the land is turned in May for the next crop. Cereals used most commonly here for the cover crop are oats, rye or barley. The legume species have not been found satisfactory for cover crops.

There are several good reasons for cover cropping instead of leaving the land bare between tobacco crops:

1. It prevents wind erosion. Most tobacco fields are sandy and light and, therefore, strong winds blow away much of the fertile top soil if it is left bare during nine months.

2. It reduces water erosion. Although most of the tobacco country is quite flat and erosion is not as great a problem as in more hilly regions, nevertheless, heavy rains even on gentle slopes of sandy soil may cause both sheet erosion and gully erosion. The roots of the cover crop hold the soil and dam back the streams to prevent or at least reduce the starting of gullies.

3. It maintains the humus content of the soil. Cover crops, in addition to the application of considerable organic materials in the fertilizer, do not actually *increase* the supply of humus in the soil but they at least keep it from decreasing in a sandy soil (36:230).

4. The mass of roots of the cover crop keeps the soil in a better physical condition, looser and less apt to pack in the spring.

5. Probably the most important benefit of the cover crop is derived from its capacity to prevent loss of nutrients between seasons. After the tobacco is harvested, there is a considerable residue of available nitrogen, potash, calcium, etc., a part of which is readily leached away by heavy rains. The roots of the cereal plants absorb the nutrients as fast as they come into leachable condition and store them in their tissues. When the cover crop is turned under in May, the same

nutrients are liberated by decay and are readily absorbed by the growing tobacco plants. It makes very little difference whether the cover crop remains alive throughout the winter (*e.g.* rye) or dies when the ground is frozen (*e.g.* oats). In experiments at Windsor (Experiment Station Bulletin 350:487), the quantity of nutrients saved annually by an acre of oats cover crop measured as follows:

Nitrogen	55.73	pounds
Calcium oxide	61.68	"
Potassium oxide	28.38	"
Magnesium oxide	13.41	"

The rate of seeding for all the cereal cover crops is about two bushels per acre.

None of the cover crops actually *adds* plant food to the soil except the leguminous crops (seldom used). Yet, in the ways indicated above, they can play a big part in maintaining the fertility and good tilth of tobacco soils.

PUBLICATIONS ON TOBACCO FERTILIZATION

By the Staff of the
Connecticut Agricultural Experiment Station

In these references the following abbreviations are used:
R = Annual Report of the Connecticut Agricultural Experiment Station
B = Bulletin of the Connecticut Agricultural Experiment Station
TB = Bulletin of the Tobacco Substation

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